BRIDGING THE GAP BETWEEN DESIGN AND USE OF PTTI SYSTEM: AN OPERATIONS PERSPECTIVE

Steven T. Hutsell
USNO Alternate Master Clock
400 O'Malley Avenue, Suite 44
Schriever AFB, CO 80912-4044, USA

William V. Bollwerk
USNO Alternate Master Clock

Abstract

Factors such as the unbounded growth in technology, as well as the desire for better, faster, and cheaper products, will always increase the pressure for advancing time transfer systems in the foreseeable future. Timing users will continually need systems with more features than before, improved robustness over previous systems, and better timing precision, stability, and accuracy than ever.

Often lost in the pursuit of timing system advancements is the perspective of the operator (user) of the system. This paper addresses elements of operations that are essential to the cohesiveness between a system and its operator. These often forgotten elements include system training, system continuity, operational simplicity, operator responsibility, and common sense in implementation.

INTRODUCTION

"A time transfer system is only as sophisticated as the confidence level of the operator/user." How often will the designers of time transfer systems stop to reflect on this simple thought?

The great technological growth the world is currently experiencing, especially since the dawn of the information superhighway, has opened the door for countless innovations for countless products in countless time transfer applications. Ultimately, though, if a customer doesn't feel comfortable with the operation of a new product, the countless innovations may prove to be more counterproductive than useful.

Advances in the determination, maintenance, and distribution of PTTI will require additional insight in the needs that drive such advances, and will also require improved understanding of how to best implement such advances with minimal risks of service interruption.

While continuing to advance on the technological front of timing systems, we must not forget the need to ensure that the operators of these timing systems have the confidence to accept the systems that utilize state-of-the-art advancements.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **DEC 1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE **Bridging the Gap Between Design and Use of PTTI System: An Operations Perspective**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Naval Observatory,Alternate Master Clock,400 O'Malley Avenue, Suite 44,Schriever AFB,CO,80912-4044**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA415578. 30th Annual Precise Time and Time Interval (PTTI) Systems and Applications Meeting, Reston, VA, 1-3 Dec 1998

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

DESIGNING FOR OPERATIONS

Typically, the two major factors developers take into consideration in the design of a timing system are performance and price—a customer will show interest in a product if it meets timing specifications, without incurring an unacceptable financial tradeoff.

While not interfering with these two important goals, the design of a timing system should also incorporate theory about the *realistic operation* of that system. How a system should theoretically work only matters when that theory is allowed to operate in a realistic environment. In the real world, life isn't perfect, and the greatness of a system will depend on how it performs when adversity arises. Timing systems should be ready to respond to adversities—"nominal case" software coding *will* eventually become a problem—*at the worst possible time*! After all, a PTTI system is only as good as its worst day.

System Documentation

Documenting the design of a system is not always the most enjoyable aspect of system development. But, for many reasons, it is arguably the most important aspect. Documentation should never be considered an "afterthought" of system development. Rather, the designers should treat documentation as an activity parallel to such activities of coding, building, and testing.

Documentation is essential to configuration control and management. When a customer is trying to operate a system, he/she must know how it's *supposed* to operate, for two reasons: a) to keep the customer protected from the pain of undesirable surprises, and b) to allow the customer to know when something *isn't* working the way it's supposed to, and thereby allow the operator to intervene, as appropriate.

Documentation ensures accountability. Many timing applications involve the use of multiple systems interconnected in a typically complicated fashion. By understanding each component of a system, the user/operator can proactively configure his/her application such that no components will interfere with the optimal operation of the other components. And, when something doesn't work, accountability, through documentation, expedites the anomaly resolution process. In essence, documentation can significantly reduce confusion, and can also help to resolve disagreements quickly.

The format of documentation may not be as important as the existence of documentation. However, the format becomes most useful when it's geared towards optimal absorption of content by the reader, who, again, is the operator/user. Different applications will suggest the need for differing formats. Often, though, similar designs can benefit from the use of similar documentation formats.

The purpose of documentation is to describe the purpose of the system, for the perspective of the operator. Documentation provides understandable information, in an efficient manner, to the system user. Documentation is optimal when it can serve the knowledge needs of the user, without *overwhelming* the user.

System Training

In many military operations, the operational readiness of an organizational mission literally lives or dies in the execution of approved standard operating procedures. The 2d Space Operations Squadron (2 SOPS), responsible for command and control of all operational Global Positioning System (GPS)

satellites, is perhaps today's flagship example of this principle. The enormous success of GPS has resulted, in large part, from certified space operations crewmembers who exhibit outstanding checklist discipline, and to the others within the squadron who facilitate accurate checklists for use by those operators.

In 2 SOPS, classroom training provides only *preparation* for on-the-job training. Many can relate to the necessity for having this understanding. How many times have we taken a C class, a UNIX Introduction, or a Windows seminar, only to find out that once we get back to our desks, we require more familiarization? The reason for this is simple. Though the classes we pay for may serve as excellent building blocks for training, each particular operational environment is unique. This becomes increasingly true as technologies become more and more diversified. As such, from now on, truly no one can reasonably expect any classroom training to completely fill the whole training square. Nothing beats the familiarization and orientation that on-the-job training provides.

System training proves itself sufficient if it can serve the purpose of adequately describing how a system will work, but truly excels when it describes *how the human being will work with the system.*

Operational Continuity

"The more something changes….." You know the rest. This statement hits home more than we realize. We must ask ourselves, "How much of our work time do we spend creating something innovative, compared to the time we spend re-inventing the wheel?" Many of us share the experience of spending many hours re-working something, simply because the originators of a system didn't take the time to properly envision the need for system modularity.

We often forget the importance of not sacrificing the future for the present. Short-term fixes are no substitute for *long-term solutions*. While alleviating symptoms of problems, true accomplishment occurs when we can identify and correct the *causes* of our problems.

Operational Simplicity

Simplicity isn't always that simple. Additional system features can add robustness, but can also increase confusion. The more bells and whistles a system has, the less each one may be understandable to the operator/user. When more bells and whistles sound, the higher the likelihood of operators tending to ignore alarms, simply because they're receiving too many.

Often, designers will add features that, on paper, seem to show potential for improving operational performance. However, if the designers don't have a solid perspective of what the true needs of the operator are, such designers may end up complicating matters more than improving matters.

Such confusion often finds its way into the GPS community. One particular example involves the classic *accuracy vs. stability* debate. To many experts in the clock community, the natural intuition is to believe that the more accurate the clocks at the GPS monitor stations, the better. To an extent, and in the right context, this intuition has some truth. However, what many in the timing community may not always understand is that the performance of GPS actually depends much more on *stability* than accuracy. Whether in navigation or time transfer, the performance of GPS is largely dependent on the stability of the GPS Composite Clock. The stability of the individual frequency standards (in both monitor stations and satellites) contributing to GPS time is paramount to ensuring Composite Clock stability. Sacrificing

stability for absolute frequency or time accuracy at GPS monitor stations can actually *degrade* GPS performance [1].

The above issue is merely one example. Many military communication systems prefer accuracy over stability. Many digital communication systems, such as local area networks and the World Wide Web, may not care too much about accuracy and stability, and actually may care more about simple operational continuity. Most operators of PTTI systems look for the right combination of stability, accuracy, and operational continuity. The mix will invariably be user-dependent.

Often, the best solution to a challenge will be the least intuitive, but the simplest in design and infrastructure. Remember the KISS principle: *Keep It Simple, Scientist!*

OPERATIONS IN PRACTICE

The success of a timing system, of course, doesn't merely rest on its design. Yes, operators make or break a well-designed system. Though 2 SOPS commands and controls a superbly designed satellite system (GPS), using sophisticated navigation and time transfer software, much of 2 SOPS's operational success over the years is directly attributable to the dedication of the personnel who make the day-to-day difference in the operational availability and accuracy of GPS.

Coordination

The importance of coordination in the operation of a system is as follows: our activities may affect more people than we might think—our activities might be more *important* than we may think.

How many times in our corporate world have we felt "cubicles away, yet worlds apart"? How often do we forget that simply taking the time to walk over to our co-worker could help prevent a problem before it can even occur? How simple it seems, yet how uncommon in practice it occurs, that we take a minute or two to pick up the phone to check with others before making decisions that could affect them significantly?

How eager many are to offer suggestions and recommendations, but how often are we too lazy to *ask* for them? Ultimately, if we are working on something that others will eventually use, we best benefit when we actively solicit their feedback. And, sometimes simply opening the door for the opinions of others isn't enough--sometimes we absolutely have to *fight* for feedback.

The problem with blind spots is that we never know just how large they are! We must be careful when we make assumptions. When we assume, what we truly assume is responsibility for the repercussions incurred if we're wrong! One of the most common mistakes we make is when we assume that communication lines are foolproof. Unfortunately, in this technological age, along with advances in communications comes the increased likelihood of communication breakdowns. E-mails can get lost, people can misinterpret tone, and *others* will sometimes make incorrect assumptions. The key to alleviating these natural problems is the never-ending conviction to *always follow up*.

Responsibility

We all must accept various levels of responsibility in our particular, unique work environments. We must be reasonable, not just to others, but to ourselves, when we accept responsibility, explicitly or implicitly. We must set *reasonable* goals, and prioritize.

By accepting responsibility for a system, we must think not only in terms of immediate explicit responsibility, but also in terms of *long-term, implicit* responsibility. We all have learned international lessons about the impacts of when we don't responsibly act with foresight—we've seen many time bombs—Y2K is perhaps our generation's most egregious example.

Though easier said than done, we shouldn't ever cover up problems; rather we should learn from problems, and *let others learn from them as well.* People will respect us more in the long term. The more one tries to cover up a problem, the less likely that problem will be able to experience the benefits of a *solution*!

When we take control of a project (and subsequently take credit for that project), we must simultaneously take *accountability* for that project. Trust is integral to the transfer of responsibility. We can best earn the trust of others when we're willing to accept the accountability that parallels the control over particular projects. If we're going to take advantage of people to further our careers, we should first take advantage of ourselves, and our own integrity.

Common Sense

"It's realistic to be optimistic, but even more optimistic to be realistic." The best solution for a problem will most likely be *situation-dependent.* One makes the best progress in problem solving when he/she approaches and examines each problem uniquely.

For many years, many in the timing community had, via empirical analysis, identified what appeared to be a 12-hour timing periodic in the broadcast GPS signal. Many inferred that what they were observing was a 12-hour periodic in GPS time, and some even concluded that the periodic somehow must have been due to some quirk in the GPS steering algorithm. In reality, however, as presented in the previous year's PTTI Meeting, the 2 SOPS Ephemeris Enhancement Endeavor (EEE) was able to reduce the 12-hour periodic to the noise level of the GPS Master Control Station estimator, strictly by improving satellite ephemeris and solar pressure state estimation [2]. The EEE team was able to rule out the GPS time steering algorithm as the culprit of this periodic, and, at the same time, for the most part, alleviate the periodic, without even touching the GPS steering algorithm.

The above example points out that, when one takes the time to give the unique attention that a unique problem deserves, he/she will often take the course of action best suited for his/her long-term interests, and help to prevent making the original problem worse. Knee-jerk reactions can result in injury! Taking the time to properly assess what's truly going on can ensure safe, progressive improvements in operations.

CONCLUSION

No portion of the above text truly presents anything new or innovative. The thoughts conveyed in the above text are convictions most all of us have, whether consciously or subconsciously. Often, a natural progression in our technological revolution is to become preoccupied with the technical aspects of a great system, while forgetting to consider properly the operational needs of the user of the system itself. This behavior is a perfectly natural characteristic of human nature in the technological age.

Designers of PTTI systems excel by staying cognizant of the requirements, goals, and expectations of the operator. Effective lines of communication are essential. Designers who fail to recognize the time-honored "customer first" principle will fail to grow and may eventually fade into a caretaker status, or much worse.

We all want to harness the benefits of the many technical advances that are occurring literally on a daily basis. At the same time, however, in order to take advantage of those technically advanced systems, we must understand how to bridge the gap between the design of those advances, and the operational use of those advances. The road to failure is paved with good intentions. The road to success is best driven by confident, responsible, trained, qualified operators.

ACKNOWLEDGMENTS

The authors would like to thank the dedicated operators of 2 SOPS, as well as our dedicated co-workers at USNO, for their inspiration, and for the great working relationship between the two agencies.

REFERENCES

[1] S. Hutsell, 1996, Discussion comments during the 27th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, 29 November – 1 December 1995, San Diego, California, USA, pp. 48-49.

[2] J. Crum, S. Hutsell, and R. Smetek Jr. 1998, "The 2 SOPS Ephemeris Enhancement Endeavor," in Proceedings of the 29th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, 2-4 December 1997, Long Beach, California, USA, pp. 117-130.

Questions and Answers

MIHRAN MIRANIAN (USNO): Steve, you might want to comment on the fact that UTC did not run off.

STEVEN HUTSELL (USNO): Yes, good point. Mihran pointed out the fact that because GPS provides the correction term for the GPS minus UTC offset in Sub-Frame 4, page 18 of the NAV Message, the 270-nanosecond runoff that you saw did not directly translate into 270 nanoseconds of UTC time recovery to users, because for the most part daily updates as a result of downloads from USNO to 2SOPS did occur. So that at least it minimized the degradation and thankfully was able to keep the very top blue number under 28 nanoseconds, which is the specification.

LT. DAVID CRATER (2SOPS, Schriever AFB): Steven, I wanted just to ask if you had a chance to get a group of people in a room, people that designed navigation and time-transfer systems for solving those types of problems. What would you say to them in terms of improving their thinking on solving these problems and incorporating the types of principles that you have talked about, as opposed to solving a type of problem that has a well defined set of things that need to be addressed? From a technical point of view, how would you tell them to incorporate the types of operational issues that you have talked about?

STEVEN HUTSELL: Obviously I am going to bias my opinion on the fact that I have spent most of my time being an operator as opposed to being an analyst outside of operations. Therefore, my opinion is going to be inherently conservative; and part of that opinion was formed by working in a squadron, which you are now in, that runs very efficiently and very effectively because you have proven procedures and check lists. I guess my biased suggestion would be to examine the problem very carefully and not to make hasty decisions. In the case of this Colorado Springs event, there was enough time to get enough people together as a "Tiger Team." Unfortunately, for various reasons, that just did not happen.

We are not in a business where we have to make decisions so quick that the safety of the world is going to depend on it over a few minutes. We are not launching ICBMs, for instance; but, at the same time, we do not have that much time to resolve a problem. In the case of GPS, everything is geared around 24-hour predictions; uploads are done 24 hours a day; downloads from USNO are done once every 24 hours. That is basically the general time frame you have to respond in.

The answer to your question is: Just try to maintain a delicate balance of getting a concrete answer, but not taking much too much time so that the problem lingers on – if that is any help.

JAMES DeYOUNG (USNO): I just have one comment. At the Naval Observatory we have had a number of people who had a great deal of experience retire in the last few years. We have already gone through that experience. There are other places – especially in this room, I see a lot of people that have been around PTTI for a long time who will potentially be retiring in the near future. The goal is that basic knowledge is already out there, but there is still no replacement for experience in time and frequency. There are so many complex systems in the field today that we have to get younger people experienced in and understanding of the systems. It is great to approximate a clock with power-on noise and all of these things; but in the data I look at day to day, there are so many noise processes involved together that the simple models are not going to be sufficient. In my opinion, in the out-years, when you go to two-way time transfer and especially GPS carrier phase over long distances; you are going to be risking a lot. There is a lot of stuff going on that is scientifically interesting and are goals for bigger budgets in the future years.

STEVEN HUTSELL: Right. It enforces the tradeoff of how much performance you want versus how much redundancy and safety you have. As we are getting more technical in our systems, the more risks we have of things breaking and more people being around not really understanding the quickest way to solve it. It is a dilemma.